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FIELD NOTE NUMBER

56

OBSERVATIONS ON THE SPRING MIGRATION OF LESSER SNOW AND BLUE GEESE THROUGH SOUTHERN MANITOBA

H. BLOKPOEL

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In the belief that rapid exchange of information is of the utmost importance to a solution of the bird problem, the Associate Committee on Bird Hazards to Aircraft has decided to release rough field notes as soon as they are produced, rather than to wait until these data would normally appear in formal reports.

These field notes are produced for information and will not usually receive the editorial care usually given to formal reports.

It is hoped that other groups will contribute similar notes on an exchange basis.

M.S. Kuhring
Chairman
Associate Committee on
Bird Hazards to Aircraft
National Research Council of Canada

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H. Blokpoel

Canadian Wildlife Service

Eastern Region Headquarters, Ottawa

October, 1971

INTRODUCTION

The eastern populations of the Lesser Snow and Blue Geese, Chen caerulescens (snow geese) winter along the Gulf Coast. Their spring migration corridors in the U.S. are described by Bellrose (1968). The geese migrate in a general north-northwesterly direction with stops at traditional staging areas. Their last major stop in the U.S. before entering Canada, is the area near Devil's Lake, North Dakota. The first main staging area in Canada used to be Grant's Lake, about 30 miles northwest of Winnipeg, Manitoba (Soper, 1942), but since the early 1940's this area has not been used (Man. Conservation Extension Branch, 1966), and many staging snow geese are now seen in southern Manitoba and northern North Dakota along the international border.

When migrating from there to James and Hudson bays the snow geese fly in northeasterly directions (Hochbaum, 1955; Bellrose, 1968 and Canada Department of Transport, 1970) often in large flocks (average flock size about 200 birds) at altitudes of up to 5,000 feet or more (H. Hosford, pers. comm.). A large proportion of the migrating geese crosses the Terminal Control Area of Winnipeg International Airport (an area with a radius of 30 n. mi. and the centre at the airport). In spring 1969 a flock of snow geese was struck by a civil airliner 24 n. mi. northeast of Winnipeg. The aircraft was seriously damaged. The Associate Committee on Bird Hazards to Aircraft of the National Research Council of Canada was requested to monitor this migration in spring 1970.

The operational results of the project were reported by Dr. W.W.H. Gunn in a paper presented at a meeting of the Flight Safety Foundation in Washington, D.C. in fall 1970 and distributed as Appendix D to the minutes of the 48th meeting of the Associate Committee.

The present report documents the biological information obtained during the spring 1970 snow goose migration project: it outlines the general course of the migration, describes the main wave in detail and briefly reports a minor migratory movement that preceded the main flight.

During spring 1971 the snow goose migration was again monitored. The operational results of the spring 1971 project were presented by Blokpoel at the 50th meeting of the Associate Committee and his report was attached to the minutes. It is likely that the spring 1972 migration will be monitored as well. The final report on the migration of the snow geese will thus be based on data for three consecutive spring seasons and will put the present results in a much broader perspective.

METHODS

Visual observations of both resting and migrating snow geese were made on the ground. Regular observations in the early morning and evening were made at the Winnipeg Air Traffic Control (ATC) Tower from April 29 to May 8. In the Carman area (37 miles southwest of Winnipeg) regular observations were made from May 8 to May 17. Apart from our routine observations many accidental sightings were reported by reliable observers in and around Winnipeg. On May 16 two air surveys were made in the vicinity of Winnipeg.

Radar techniques. Time-lapse films were taken from the screen of the AASR-1 23-cm surveillance radar of Winnipeg International Airport from May 2 to May 19. The range was set 60 n. mi. This screen was fitted with a clock and data tab. The antenna made six revolutions per minute. Each second sweep was recorded on one film frame. Solman (1969) gives details of the camera setup and the manual of the Civil Aviation Branch (1967) describes the 23-cm AASR-1 surveillance radar.

As the snow geese migrate in spring in northeasterly directions, in large flocks and at altitudes of up to more than 5,000 feet, one would expect the echoes of the goose flocks to be big, non-fluctuating, moving at a steady speed and in a straight course in directions between north and east and visible for many miles on the screen. All echoes with these characteristics were considered 'goose echoes'.

It was impossible to confirm that 'goose echoes' on the AASR-1 screen were indeed caused by flocks of migrating snow geese, but in a few cases visual confirmations were obtained for 'goose echoes' on the screen of ASR-5 radar at Winnipeg Airport. The ASR-5 is short-range 10-cm surveillance used for terminal air traffic control (see Civil Aviation Branch, 1967 for details of the equipment).

Directions of 'goose echoes' were determined from tracks obtained by projecting the radar film on a sheet of paper and manually tracking the path of the echoes with a pencil. Ground speeds of 'goose echoes' were obtained using a Vanguard Motion Analyzer. Heights of the migrating geese were obtained from the Precision Approach Radar (PAR) of ATC, Winnipeg, in combination with visual observations from the ATC Tower. Details of the 3-cm PAR are given in the manual of the Civil Aviation Branch (1967). The mean airspeed of the geese was found by vector analysis of mean ground speed and direction of the geese and the wind speed and direction at the height the geese were flying. The density of 'goose echoes' was obtained by counting the hourly numbers that crossed a line 50 n. mi. in length and perpendicular to the main flight direction. The centre of the line was at a distance of 30 n. mi. from the centre of the radar scope.

Weather data for Winnipeg (surface maps, 850 mb maps, reports of surface weather and six-hourly upper air wind data) were provided by the Airport Meteorological Office. All times given in this report are Central Standard Time and all directions in azimuth degrees, True North being 360° or 0°. The direction of the wind indicates from where the wind blows, the direction of the birds where to the birds fly. Wind speeds were usually provided in knots: 1 knot = 1 nautical mile per hour = 1.15 statute miles per hour = 1.852 km per hour = .514 meter per second.

RESULTS AND DISCUSSION

I. Distribution of staging snow geese in late April and May 1970

No special study was made but some data are available: Dr. D.G. Raveling (pers. comm.) flew an air census on April 27 over the area north and northwest of Winnipeg (St. Andrews Bog, Shoal Lakes and along Highway No. 6, see Fig. 1).

He counted a total of 537 snow geese. On April 28 and 29 a road trip through southwestern Manitoba was made by Dr. J.P. Ryder, B. Koonz and D.R.M. Hatch. They counted about 63,500 snow geese with the major concentrations at Whitewater Lake, Boissevain, Cartwright, Crystal City and Pilot Mound, see Fig. 1 (D. Hatch, pers. comm.).

Dr. W.W.H. Gunn (pers. comm.) found the snow geese in North Dakota at the end of April; by May 2 the great majority of the geese had left the Devil's Lake area about 60 miles south of the Manitoba border and were probably staging along both sides of the U.S.-Canada border. On May 7 L.J. Bidlake (pers. comm.) estimated a total of 45,000 snow geese in big concentrations near Pilot Mound, Snowflake and Windygates (Fig. 1). On the morning of May 16, R.C. Hutchinson (pers. comm.) flying the route Winnipeg-Morris-Arnaud-Dominion City-Letellier-Winnipeg (see Fig. 1), counted about 9,200 snow geese on the ground, and four flocks in the air flying in a northerly direction at 1,000 to 1,500 feet above ground level (a.g.l.). Later that day (1400-1600 hrs.) I counted about 18,000 resting snow geese from the air flying the route Winnipeg-Carman-Snowflake-Manitou-Elm Creek-Winnipeg (see Fig. 1).

I have no estimate of the total number of snow geese that were staging during early May 1970 in the southern part of Manitoba and in North Dakota north of Devil's Lake. During spring 1968, A.J. Pakulak and D.B. Fogg made a ground survey south and southwest of Morden (see Fig. 1) and Pakulak (pers. comm.) estimates "the number of snow-blue geese which annually stage during the spring along the Manitoba-North Dakota international boundary to be in the vicinity of 300,000 birds". This subject is further discussed on p. 8.

II. The 1970 snow goose migration in general

II. A. The migration in general: temporal patterns

The visual observations of migrating snow geese listed in Table 1 indicate that apart from a few flocks most of the migration occurred in one big wave on May 15-17. The locations given in Table 1 are indicated in Figure 1. It was sometimes difficult for an observer to decide whether a flock of geese flying in the 'right' direction was migrating or not, especially when there was only one flock involved and when the observation was made in or near a staging area. Thus some of the sightings of migration may be observations on local flights (see Table 1, May 14). Note that all estimated directions vary from N to E and that most altitudes are below 2,000 feet a.g.l.

The sightings suggest that the main wave started on the afternoon of Friday, May 15, when many migrating flocks were seen near Delta and Marshy Point. In the early evening one flock was reported just north of Winnipeg and Bidlake reports "main migration after clearing of skies from south and west in the late evening" (pers. comm.). Migration must have gone on into the night because flocks were heard between 2100 and 2200 hours. On the morning of Saturday, May 16, migrating geese were seen by many observers in and around Winnipeg. I counted 48 flocks from the ATC Tower between 0800 and 1145 hours. In the early afternoon few birds were reported migrating. During an air survey from 1300 to 1500 hours (Winnipeg-Carman-Snowflake-Manitou-

Winnipeg) I counted some 18,000 snow geese on the ground. Migration apparently picked up again in the evening because migrating geese were observed by many observers. At the ATC Tower I counted some 45 flocks between 1930 and 2035 hours. Migration continued during this night as well because geese were heard in the dark. On Sunday, May 17, many migrating flocks were seen at Victoria Beach (Fig. 1) in the early morning. The last observation for Winnipeg was a flock heard at 0420 hours. No birds were seen on the ground or in the air during a ground survey by car near Corman from 0600-0800. No reports of migrating or resting geese were received after the morning of May 17. This main wave of snow goose migration over the Winnipeg area apparently started on the afternoon of May 15 and ended by mid-morning of May 17, a total of less than 48 hours.

The radar films, which started on May 2, showed small numbers of scattered 'goose echoes' on the mornings of May 3 and 4, the evening of May 5, the afternoon and evening of May 6, the morning of May 7 and the evenings of May 11 and 13. A minor movement involving more than 125 'goose echoes' took place on the morning of May 6. The main wave of 'goose echoes' (discussed on p. 11 and 12) started around 1300 hours on May 15 and ended on May 17 at about 1000 hours. Very few, widely scattered 'goose echoes' were seen after the morning of May 17. Radar filming ended on May 19.

There is a good agreement between the visual and radar observations during the main wave, but there are no records of visual observations of the movement on May 6 (a Wednesday) from 0500 to 1200 hours and at about 15-35 n. mi. west of Winnipeg. In that period the sky over Winnipeg was clouded with the measured ceiling at 6,000 feet a.g.l.

Assuming that the 'goose echoes' were indeed caused by flocks of migrating snow geese (p. 6), it is apparent from both radar and visual observations that most geese migrated in one major wave from May 15 to 17 with some flocks flying well before the main wave.

This is in agreement with a statement in the folder prepared by the Manitoba Conservation Extension Branch (1966): "Unlike most other species of waterfowl, whose migrations extend over several weeks, most of the Lesser Snow Geese move in one great flight. This movement takes place during the first week of May when the birds can be seen passing northeast over southern Manitoba on their way to Hudson Bay.". Hochbaum (1971) summarizing over 30 years of records, notes (p. 41) that the usual spring arrival date of snow geese at Delta lies between April 17 and May 1, with mass migration to the Arctic breeding grounds taking place from May 7 to 15 (p. 50).

II. B. The migration in general: topographic patterns

The sightings show that the geese were not flying along rivers, shorelines, etc., but in a broad front at least 100 n. mi. wide. I collected sightings from the environs of Winnipeg only, but I happened to learn of flights over Minnedosa and Falcon River (Fig. 1). I do not know the western and eastern boundaries of the migration corridor of the snow geese.

The radar data confirmed the broad front migration and indicated that the front would be at least 50 n. mi. wide. Due to technical problems (see p. 6) and the range setting of 60 n. mi. at the scope, the AASR-1 radar could not provide us with an accurate idea of the full width of the front. Speirs, Kanitz and Novak (1971) reported broad front goose migration over Thunder Bay, Ontario.

II. C. The migration in general: spatial distribution

Migrating flocks of snow geese sometimes appeared to migrate in small groupings: i.e., about three to eight flocks would pass in rapid succession and within view of each other, to be followed after perhaps 10 to 15 minutes by another association of flocks. The radar data showed this phenomenon too. At most times however there was a steady flow of flocks.

II. D. The migration in general: weather conditions

Some factors of the Winnipeg weather for the period May 1-18 are given in Table 2, which shows that from May 1 to 5 the winds were generally NW, except on the morning of May 2. On the evening of May 5 and all day May 6 the winds were southerly, coinciding with a rise in temperature (May 16, 1800 hours). On May 2 and 6 there was heavy cloud cover. From May 7 to the evening of May 15 the winds were NE, E or SE, temperatures low and the sky completely overcast with occasional precipitation. Very light rain showers were still recorded at 1800 hours on May 15 but by that time the winds were changing towards NW and the sky cleared in the early evening. On May 16 the winds were NW all day long (see also Table 3), the sky clear and the temperatures much higher than on previous days; in the evening the wind changed to SW. On May 17 the winds were strong and SW, coinciding with very high temperatures and light cloud cover. On May 18 the winds were NW and the temperatures much lower than on May 17.

The geese were flying on the morning of May 6 (radar data only) with a southerly flow of warm air and a clouded sky, and on May 15-17 after eight days of easterly winds, clouded skies and low temperatures. The vanguard of the main wave on the afternoon of May 15 flew with head winds, a good proportion (May 15/16) with sidewinds and the main bulk of the birds (May 16/17 and 17) with tail winds. Winds with directions differing less than 45^{o} from the flight direction are considered as either tail or head winds, all other winds being sidewinds. It seems that many geese were so anxious to migrate that they were willing to fly under less than ideal wind conditions. This fits well with a statement made in a booklet prepared by the Canada Department of Transport (1970) regarding the spring migration of geese, swans, cranes and ducks: "Normally they leave the staging areas between dusk and midnight and during the first three hours after dawn, however, they may leave at any hour of the day or night, particularly after long periods of poor weather for migration. The longer the period of unfavourable weather the greater the likelihood that the birds will depart before really favourable weather moves over the area. Normally these birds will not leave a staging area against surface winds in excess of 10 knots. Major movements, involving hundreds of thousands of birds, often follow the passage of a ridge of high pressure.".

Hochbaum (1955, p. 131-132) writes: "Let us note, too, that while the south wind favours the movement of most ducks going to the northwest, the Blue and Lesser Snow Geese travel to the northeast, directly across the main flow of air.". In 1970 a large proportion of the snow geese flew across a northwesterly rather than southerly wind.

III. The main wave of the 1970 snow goose migration

III. A. The main wave: confirmation of the 'goose echoes'

Whether or not a flock of birds will show up on the radar depends on the number of birds per flock, the range, height and aspect of the flock, echoeing area of one bird, on the overall performance of the radar, on the radar aids used (like Moving Target Indicator, Circular Polarization, Fast Time Constant, Sensitivity Time Control) and on the present weather. Whether or not two flocks flying closely together will be shown as two separate echoes depends on the radar resolution in range and azimuth and on the sizes and ranges of the flocks. Because of its shape the rotating radar beam does not cover the air space above the radar site, thus causing a blind spot in and around the centre of the radar screen. Richardson (in prep.) discusses the effects of different radar settings on the number of bird echoes on the screens of the AASR-1 and ASR-5 radars.

I have no proof that all 'goose echoes' of the main wave were indeed from flocks of snow geese. However, I have proof that some of them were caused by snow geese and there is circumstantial evidence that at least the majority of the day-time 'goose echoes' represented flocks of snow geese.

On May 16 from 0800 to 1145 hours 44 flocks were visually observed from the ATC Tower and from 1930 to 2035 hours 45 flocks. All 89 flocks looked like migrating geese with the exception of one flock of five Double-crested Cormorants. About half of the flocks were close enough to be identified specifically. They were all snow geese. In the morning most flocks were flying at 500 feet to 1,500 feet a.g.l. (estimates by the air traffic controllers) and in the evening at about 1,200 feet to 1,400 feet a.g.l. (shown by the Precision Approach Radar, see Table 6). All flocks were flying in northeasterly directions and all were large (at least about 100 birds).

Two displays of the ASR-5 surveillance radar are used in the ATC tower, from which we made visual observations. I did not determine quantitatively how many goose flocks of what size were showing up as 'goose echoes' on the screen of the ASR-5 radar because (1) the screens were not available for our exclusive use, (2) the closer in the birds the smaller their echoes and the less their appearance as 'goose echoes', (3) echoes of birds flying at tangential azimut (i.e. having no radial speed) are cancelled by the radar's Moving Target Indicator and (4) the snow geese tended to come in waves with loose associations of flocks, which often joined, separated and regrouped.

Despite the lack of quantitative data I feel it is safe to say that most, if not all, of the visually observed flocks were producing echoes on the ASR-5 screen. In fact many flocks were sighted using the position of their echoes on the screen. The further out the approaching flock the bigger its

echo. Many good 'goose echoes' at 10 miles decreased in size and sometimes even disappeared when close to the centre of the scope (within about 3 miles). The radar films showed that all 'goose echoes' on the ASR-5 also showed up on the AASR-1 screen and usually to greater distances.

Study of the films taken from the screen of the AASR-1 showed that most of the 'goose echoes' were of similar size and moving in similar directions, at similar speeds and appeared on or disappeared from the screen at similar ranges. This suggests that most of the 'goose echoes' were probably representing only one type of bird.

There was in general a good agreement between the visual observations and the presence of goose echoes on the radar screen. The correlation could not be carried out quantitatively because of the technical difficulties mentioned above and the unreliability of the visual height estimates.

The observers never reported heavy migration of other species migrating simultaneously with and in the same direction as the snow geese. I know no other species that migrates over the Winnipeg area, both during day-time and night-time, in large numbers of large flocks, in northeasterly directions, in the middle of May, with airspeeds of about 30 m.p.h. and that therefore could be responsible for the bulk of the 'goose echoes' on our radar films. I think it is justified to conclude that the great majority of at least the day-time 'goose echoes' actually represented flocks of migrating snow geese.

III. B. The main wave: numbers of 'goose echoes'

Hourly numbers of 'goose echoes' are given in Table 4. The first 'goose echoes' were seen in the early afternoon of May 15 in the NW quadrant. These echoes did not cross the 50 n. mile frontline (see Methods) and are thus not given in Table 4. Their directions, however, are given in Table 5.

There clearly is a peak each night. Although we saw the migration increasing during both evenings and know that the geese were flying at night we have no proof that the large numbers of night-time 'goose echoes' are all caused by snow geese.

More than 2,500 'goose echoes' were counted. Usually few 'goose echoes' were seen outside the 50 n. mile front, which may be due to the paucity of goose flocks or to the effect of the Moving Target Indicator (see Richardson, in prep.). It is possible that the 50 n. mile front does indeed include the majority of the flocks. The general staging distribution (Fig. 1) and directions of migration (Table 5) indicate that a good proportion of the snow geese must have passed within 25 n. miles of Winnipeg.

It is impossible to calculate what proportion of the migrating birds crossed the 50 n. mile front because of changes in direction of migration (Table 5), different departure dates and times and different densities on the staging grounds.

Assuming that the 50 n. mile front intercepts about 75 to 50% of the snow geese passing through Manitoba, and an average flock size of 200 birds a very rough estimate for the total number during the main wave would be

650,000 to 1,000,000 snow geese.

It was hard to estimate the average flock size because the geese sometimes flew in large 'superflocks' consisting of up to 8 flocks, loosely strung together. Individual flocks would often separate from and rejoin the 'superflock'. The radar films showed this phenomenon as well: big echoes would sometimes split up in 2 or 3 smaller ones, which sometimes fused again. H.R. Hochbaum (pers. comm. to A.L. Pakulak) estimates the average flock size as 200-250 birds. My own estimate is about 200. This of course pertains to day-time flocks only. At night the flocks may well be somewhat smaller because night-time 'goose echoes' are often somewhat smaller than day-time ones.

My estimate of a total of 650,000 to 1,000,000 snow geese is very high compared with Pakulak's estimate of 300,000 staging snow geese for spring 1968 but agrees somewhat better with the estimates of the 1969/70 winter populations in the Southern U.S. (361,000 for the Mississippi and 359,000 for the Central Flyway, total 720,000; U.S. Bureau of Sport Fisheries and Wildlife, 1971). Based on discussion held with the Blue/Snow Goose Subcommittee of the Central Flyway Technical Section, there is some indication that wintering numbers have been under-estimated in recent years (Dzubin, pers. comm.). According to Bellrose (1968), 90% of the snow geese migrate through southern Manitoba and their numbers at Sand Lake Refuge, S.D. varied from 200,000 to 500,000.

III. C. The main wave: times of take-off from the staging grounds

Apart from the peaks for both nights, Table 4 shows a minor peak for the morning of May 16. On the night May 16/17 the peak number was more than twice as large as on May 15/16. Both the beginning and apex of the nightly peak (as recorded 30 n. miles NE of Winnipeg) were about two hours later on the night of May 15/16 than on May 16/17. That was probably due to the fact that the geese were flying in different directions and at different speeds presumably coming from different staging areas (see Tables 5 and 8 and Figure 1). As mentioned before a large proportion (May 15/16) flew with north-westerly cross-winds but the main bulk (May 16/17) used the south-westerly tail-winds.

By back-tracking the major peaks (Table 4) to the staging areas (using the ground speeds of Table 8 and directions of Table 5) it appears that, while the geese started to take off from about 1700 hrs., the largest departures must have occurred from 2000 to 2100 hrs., or just around sunset. Substantial numbers of geese must have continued to take off till at least midnight because of the high numbers of 'goose echoes' in the early morning hours of May 16 and 17. Especially during the night of May 16/17 geese must have departed after midnight as well. Back-tracking the minor peak on the morning of May 16, it appears that the geese started to fly from about 0630 hrs. and that departures peaked about 0900 hrs. or about 5 hours after sunrise.

III. D. The main wave: weather conditions at the time of departure

Although a few goose echoes were seen during the afternoon of May 15 on

the northwest quadrant of the scope, the geese started to depart in larger numbers from 1700 hrs. onwards with a peak from about 2000 to 2100 hrs. The weather for the Boissevain-Cartwright (Fig. 1) staging area at that time is not exactly known but in all likelihood it was cloudy with a northerly or northeasterly surface wind at about 10 n.mi/hour. Winds at the 2,000 and 5,000 ft. levels were northerly as well. Thus the snow geese departed under improved but still rather poor weather conditions.

III. E. The main wave: directions of the 'goose echoes'

The average hourly directions of 'goose echoes' are given in Table 5, which shows very little change in the hourly mean directions (generally about 70°-75°) from the afternoon of May 15 till the morning of May 16 when a sudden shift occurred towards more northerly directions (generally about 40°-50°). From then on there is a gradual but consistent shift towards still more northerly directions and by mid-morning May 17 the mean direction is about 20° to 25°.

The almost constant mean direction of 70°-75° from May 15, 1300 hrs. through May 16, 0800 hrs. suggests that the migrating geese belonged to populations with southern breeding ranges or migration routes and the fact that this course was maintained notwithstanding a wind shift from northeast to northwest (Table 3) indicates the capability of the snow geese to correct for winddrift.

The abrupt change in flight direction on May 16, at 1000 hrs., suggests that after the night flight has passed (see Table 4) the morning flight consisted of geese of populations with more northern breeding areas or migration routes. During the night May 16/17 (with very constant directions from 1900 through 0400 hrs.) and the morning of May 17 (with small numbers in fairly northerly directions) still different populations of snow geese may have been migrating. This suggests that the Mississippi and Central Flyway snow geese migrate north through the same corridor but after their common stage in southern Manitoba and northern North Dakota fly separately to their different breeding areas. This agrees very well with the view of H.G. Lumsden, who writes (pers. comm.): "My impression is that Blue/Snows fan out from the prairie staging area over about a 90° arc and hit the sea coast all the way from Moosonee to Churchill".

The great change in wind direction from NE (on May 15) to SW (on May 17) and the observed change in mean migration direction, combined with the changes in density suggest that birds of the more southern populations took wing at a time when birds of the more northern population waited for a further improvement in the weather.

III. F. The main wave: flight altitude

It is hard to visually estimate the height of migrating birds and such estimates are usually of limited reliability. Visual estimates of the altitude of the snow geese (Table 1) show good general agreement with the height data obtained with the Precision Approach Radar (Table 6). Because of it's low elevation angle the height finder of the PAR could not detect all

echoes visible on it's azimuth screen. Thus for high-flying targets at close range I only have a minimum altitude above which the birds must have been flying, making it impossible to calculate the mean flight altitude.

Table 6 shows that most geese were flying at moderately low levels (1200' to 1600' a.g.l.) and that there was only a slight tendency for the geese to climb to higher levels during the course of the night. Many geese may have continued to fly at about 1200 ft. a.g.l. throughout the nights May 15/16 and 16/17. Yet migrating Blue Geese have been reported at up to 8000 ft. (Cooch, 1955). Perhaps the snow geese were flying at the relatively low height of 1200 ft. for physical reasons such as the presence of thick cloud layers, intense turbulence, very low temperatures or less profitable wind conditions at higher levels. Apart from heavy clouds in the early evening of May 15, there was no thick cloud cover for the periods given in Table 6 (total opacity = 3 on May 15, 2300 hrs.; t.o. = 1 on May 16, 1800 hrs.; and t.o. = 1 on May 16, 2300 hrs.). It is unlikely that heavy turbulence occurred somewhere above 1200 feet. The surface temperature was 40.1°F on May 15/16 (2400 hrs.) and 54.3°F May 16/17 (2400 hrs.). Assuming 3.6°F decrease in temperature per 1000 ft. elevation (standard atmosphere) the freezing level would have been at about 2200 ft. and 6200 ft. a.g.l., respectively. Thus, especially on the second night the temperature probably did not cause a ceiling on the flight altitude.

Wind directions and speed often change with height and migrating geese might be able to detect the most profitable height. The upper air winds, as determined by pilot balloons at Winnipeg Airport, for the period May 14-19, 1970 are given in Table 2. Table 7 gives the tailwind components of the winds from surface to 6200 ft. a.g.l., using the flight directions given in Table 5. Table 7 shows that on May 15 (2300-2400 hrs.) the lower the flight height the more profitable the wind conditions. The fact that the geese were flying at 1200 ft. may be explained by assuming that the geese need a certain minimum altitude when flying at night. The data for May 16, 1700-1800 hrs. do not show a clear trend; those for May 16, 2300-2400 hrs. show that the majority of the geese were flying at the most economic height.

III. G. The main wave: ground speeds

Ground speeds are given in Table 8. Because of the highly interesting situation on the afternoon of May 15 (a strong head-wind) and the morning of May 15 (a strong head-wind) and the morning of May 17 (a strong tail-wind) more speeds were calculated for these periods than for the rest. Table 8 shows that on the average the 'goose echoes' were moving more than twice as fast during the late morning of May 17 than during the early afternoon of May 15.

The greatest and smallest individual ground speeds recorded were 17 and 73 kts., the average hourly ground speeds varied from 24 to 62 kts. The greatest ground speeds for geese (species not certain but very likely a mixture of snows and Canadas) in fall over Thunder Bay found by Speirs et al (1971) were 29 and 80 kts., while average hourly groundspeeds varied from 41 to 57 kts.

The spread in individual ground speeds of the 'goose echoes' may be caused by pooling echoes from birds with differences in altitude, direction and rate of climb and by the inclusion of non-goose echoes as 'goose echoes'. The gradual change in hourly mean ground speed is almost completely due to changes in wind direction and mean track directions of the echoes, as is shown in the next section.

III. H. The main wave: air speeds

I calculated the mean air speed and mean heading of the geese, as shown in Table 9, from the mean ground speed (Table 8), the mean track direction (Table 8), the modal height (Table 5) and upper airwind data for Winnipeg (Table 2). The data for the period May 16, 1100-1200 hrs. were calculated using the rough visual height estimates (1000-2200 ft. a.g.l., Table 1) and assuming a wind of 310° at 10 kts. (note that the winds for 1200 and 2200 ft. are practically the same, Table 3). Calculations for the period May 17, 0500-0600 hrs. (see Table 9) were based on only one observation on the height by G. Townsend from a light aircraft (Table 1).

The mean air speeds showed very little variation (from 26.6 to 33.3 kts.) compared to variation in the mean ground speeds (27.2-57.2 kts.). It is likely that this variation is not due to different climb rates, because for the first four periods of Table 9 the birds were probably in level flight (see also p. 10). The limited data suggest that the airspeed of migrating snow geese is constant and does not vary with different wind speeds or wind directions.

Tucker and Schmidt-Koenig (1971), working on a number of birds of different species mostly flying at altitudes less than 50 meter and "cruising" cross-country, remark "The air speeds we measured are too variable to support the hypothesis that birds fly at closely regulated air speeds to conserve energy". Their results and mine are not fully comparable because the snow geese were making a long-distance migration (probably a non-stop flight to Hudson and James Bays) whereas the "cruising" birds studied by Tucker and Schmidt-Koenig were probably engaged in daily activities like looking for food or a place to rest, etc.

Air speeds for fall migrating geese, calculated by Speir et al. (1971) varied from 24 to 36 kts., with an average value of about 30 kts., closely similar to my findings.

IV. The minor movement on May 6

This movement was hard to evaluate because a heavy NNW movement of big echoes occurred at the same time, the quality of the radar film was rather poor and no data were available from 0800 to 1030 hrs. The first 'goose echoes' were noticed at about 0400 hrs., they peaked between 0500 and 0800 hrs., and by 1200 hrs. this minor movement had passed, although occasional, scattered 'goose echoes' continued to move. This minor movement consisted of at least 125 'goose echoes'.

The directions during the peak of the movement were as follows:

Time (CST)	Mean (°N)	Range (°N)		N
0500-0600	24	3	42	15
0600-0700	30	17	40	51
0700-0800	38	23	56	38

Ground speeds of 8 echoes determined for the period 0545-0630 hrs. varied from 61 to 74 kts. (mean = 69, s.d. = 4). As we do not know the height of the geese it is impossible to calculate the airspeed. On the other hand, knowing the direction of the birds (26°, direction obtained with Vanguard Motion Analyser) and assuming that the geese all flew at the same height at an airspeed of about 30 kts., one can estimate the birds' height, if the upper air winds are known. Upper airwinds, as measured with a pilot balloon released at Winnipeg Airport at 0515 hrs. on May 6, and their tail wind components (see p. 10) were as follows:

	Height above ground level (ft.)					
	1200	2200	3200	4200	5200	6200
Wind direction (°N) wind speed (kts.)	185/54	190/55	205/50	220/40	235/39	260/48
tail wind component (kts.)	50	53	50	39	34	28

If the assumptions are correct the geese were thus flying at about 4200 ft. a.g.l. or well below the clouds, the ceiling of which was at 6000 ft. a.g.l.

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SUMMARY

This article reports the biological information gathered during a project to monitor and warn of the spring 1970 migration of Lesser Snow and Blue Geese (snow geese) in the vicinity of Winnipeg International Airport. Visual observations from the ground and the air supplemented observations made with the Airport's AASR-1 surveillance radar and Precision Approach Radar. In early May the snow geese were staging in southern Manitoba along the international border from Whitewater Lake east to Dominion City.

Both radar and visual observations showed that the great majority (the main wave) of the snow geese flew between the afternoon of May 15 and mid-morning of May 17. Small scattered numbers of birds flew earlier with a distinct minor movement on the morning of May 6 (radar observations only). The snow geese migrated in a broad front, at least 100 nautical miles wide.

There is little proof but considerable circumstantial evidence that at least the majority of the daytime 'goose echoes' during the main wave were caused by flocks of migrating snow geese. The main wave started after a 10-day period of poor weather (northerly and easterly winds, rain, heavy overcast); the vanguard flew against headwinds, a good proportion with sidewinds and the main part with tailwinds. Some 650,000 to 1,000,000 snow geese were flying during the main wave, with major peaks during the nights May 15/16 and 16/17 and a minor one on the morning of May 16.

The radar data suggest that different populations flew at different times in different directions. Throughout the night May 15/16 the geese flew ENE (notwithstanding a change in wind direction), on May 16 NE, and on May 16/17 NNE.

During the evenings of May 15 and 16 the Precision Approach Radar showed that most geese were flying at about 1200 to 1400 feet above ground level. Individual ground speeds varied from 17 to 73 kts., and mean hourly ground speeds from 24 to 62 kts. Mean air speeds, calculated from the mean ground speeds for five one-hour periods, varied from 26.6 to 33.3 kts. It is hypothesized that snow geese migrate with constant air speed, regardless of the wind conditions.

During a minor movement of 'goose echoes' on the morning of May 6 very strong tail winds resulted in a very high mean ground speed (69 kts.).

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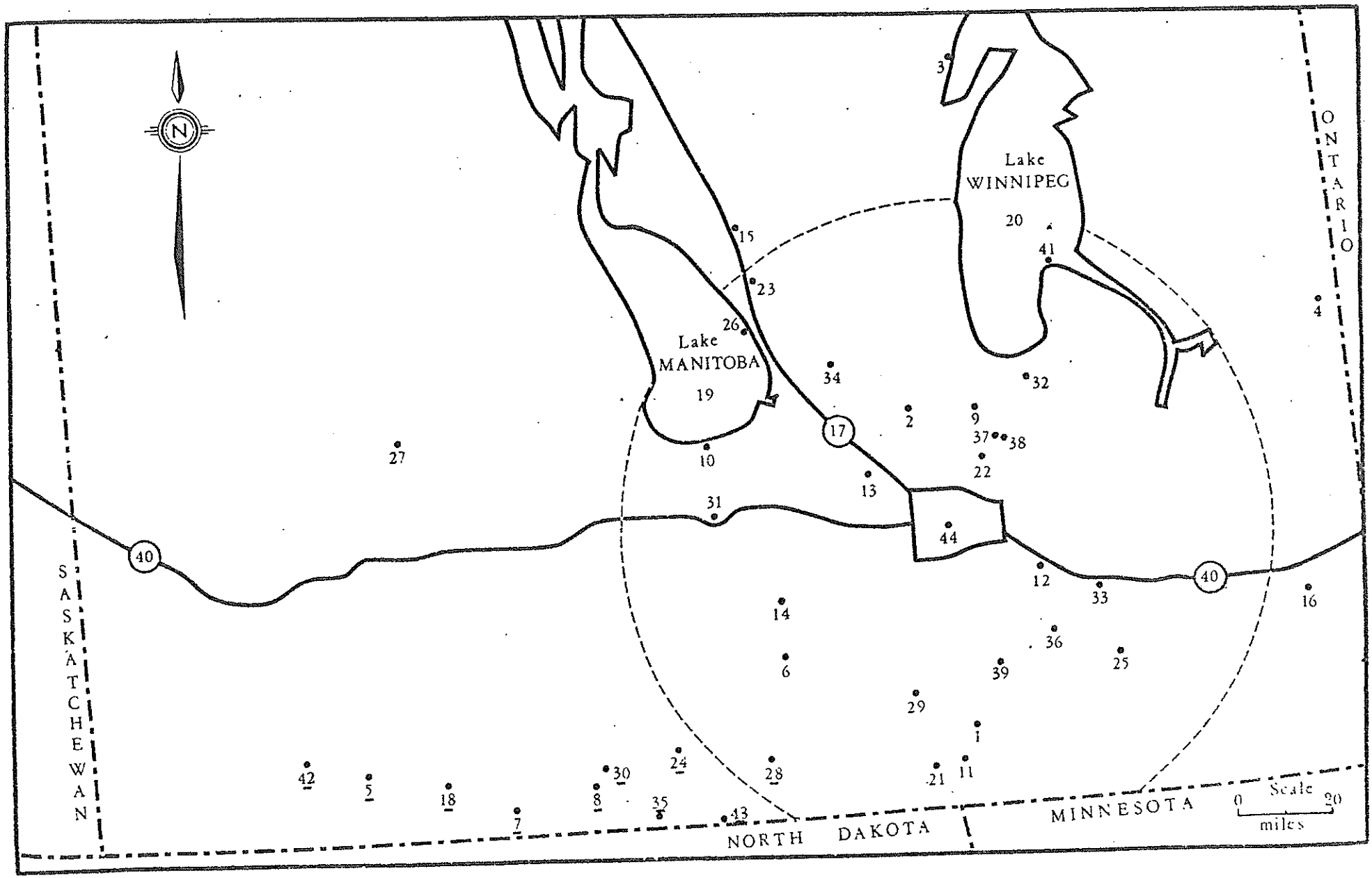

Figure 1. Locations in southern Manitoba mentioned in the text. Major staging areas are underlined. The circle indicates the range setting (69 mi) of the filmed scope of the AASR-1 surveillance radar at Winnipeg Airport. See attached table for key to numbers.

1 Arnaud

2 Balmoral

3 Beaver Creek

4 Bird Lake

5 Boissevain

6 Carman

7 Cartwright

8 Chrystal City

9 Clandeboye

10 Delta

11 Dominion City

12 Dufresne

13 Grant's Lake

14 Elm Creek

15 Eriksdale

16 Falcon River

17 Highway No. 6

18 Killarney

19 Lake Manitoba

20 Lake Winnipeg

21 Letellier

22 Lockport

23 Lundar

24 Manitou

25 Marchand

26 Marshy Point

27 Minnedosa

28 Morden

29 Morris

30 Pilot Mound

31 Portage la Prairie

32 Red River Delta

33 Richer

34 Shoal Lakes

35 Snowflake

36 Steinbach

37 St. Andrew's Airport

38 St. Andrew's Bog

39 St. Pierre

40 Trans Canada Highway

41 Victoria Beach

42 Whitewater Lake

43 Windygates

44 Winnipeg Airport

Table 1. Visual and aural observations of staging and migrating snow geese, in southern Manitoba. Spring 1970.

Date (1970)	Period (C.S.T.)	Location	Estimated Direction of Migration	Nos. of Flocks/ Birds	Estimated Height (ft. a.g.l.)	Observer	Remarks
April 25	1100	Winnipeg	-	1/225	Low	R.W. Gemmell	
April 26	0950	Winnipeg	NNE	1/200	-	G.J. Smith	
May 1	0552-0625	Winnipeg	N	1/8	<1200	J. Hines	birds below the clouds
May 3	0825	Winnipeg	N	1/109	-	G.J. Smith	60% Snows
May 5	"during the day"	Winnipeg	Nerly	2 or 3/-	2000	ATC Personnel	species unknown
May 5	"during the day"	Winnipeg TCA	-	-/-	2700	Pilot report	'geese' flying
May 8	1945-1955	Carman area	NE	2/3000+	<1000	J. Hines	followed 1 flock 6 mi.
May 12	1915	8 mi. NE of Carman	NNE	2/400+	1000-2000	J. Hines	probably migrating
May 14	0700-0800	Minnedosa	NE	-/2000	300	E. Fritzell	
May 14	1800	6 mi. E of Carman	NE	1/200	1000	J. Hines	
May 14	1840	6½ mi. NE of Carman	N	-/-	Low	J. Hines	possibly migrating
May 14	2130	Winnipeg	-	1/-	-	W.G. Leitch	heard only

Table 1. Cont'd.

Date (1970)	Period (C.S.T.)	Location	Estimated Direction of Migration	Nos. of Flocks/ Birds	Estimated Height (ft. a.g.l.)	Observer	Remarks
May 15	Morning	Minnedosa	NE	few/-	-	E. Fritzell	
May 15	0950	Delta	NNE	-/250+	-	N.R. Seymour	
May 15	Afternoon	Delta	E	many	-	H. Libby	
May 15	Afternoon	Marshy Pt.	NE	-/-	low	L. King	
May 15	1300-1430	Delta	NNE	9/1900-2000	-	N.R. Seymour	
May 15	1430-1800	Delta	NNE	-/-	-	N.R. Seymour	"birds continued flying"
May 15	1400-2000	Winnipeg-Lundar-Winnipeg	ENE	11/1700	400-800	D.G. Raveling	
May 15	1645-2000	Carman	NE	2/1200	1000	J. Hines	
May 15	Early evening	Richer	NNE	-/-	-	S.A. McIvor	"hundreds of flocks"
May 15	2012-2105	Delta	ENE	2/350	-	H. Libby	
May 15	Late evening	Winnipeg	-	-/-	-	L.J. Bidlake	
May 15	Evening	90-110 mi. WSW of Winnipeg	NE	-/10,000	-	R. Schweinsburg	

Table 1. Cont'd.

Date (1970)	Period (C.S.T.)	Location	Estimated Direction of Migration	Nos. of Flocks/ Birds	Estimated Height (ft. a.g.l.)	Observer	Remarks
May 15	2100-2200	Winnipeg	-	-/-	-	R.W. Sutton	"a number of flocks" heard only
May 16	0430-0800	Carman	NE	-/>30,000	500-1000	W. Banting & J. Hines	
May 16	0500	Winnipeg	-	several thousand	-	G.H. Townsend	
May 16	0545	St. Andrews Airport	-	-/300	400	G.H. Townsend	
May 16	0545-1000	Steinbach-Falcon L.	-	about 22,000 birds in total	-	H. Tirchman	
	1930-2015	Falcon L.-Steinbach	-		-	H. Tirchman	
May 16	0630-0830	Winnipeg-Falcon R.	NE	many/-	1500-2000	C. Dixon	
May 16	0630-1000	Delta	NE	57+/-	-	H. Libby	numbers tapered off between 0805 and 1000
May 16	0700-1300	2 mi. W of Clandeboye	NE	"very many"/-	-	R.W. Sutton	birds flying before 0700 by 1200 few birds flying
May 16	0730	Steinbach-St. Pierre	NE	-/30,000±	2000	G.H. Townsend	

Table 1. Cont'd.

Date (1970)	Period (C.S.T.)	Location	Estimated Direction of Migration	Nos. of Flocks/ Birds	Estimated Height (ft. a.g.l.)	Observer	Remarks
May 16	0750-0810	Dufresne-St. Anne	NE	6/1100	-	H.W.R. Copland	
May 16	Before 0800	Winnipeg	NE	6/-	-	ATC Tower	
May 16	0800-1130	Winnipeg	ENE	44/-	400-2200	H. Blokpoel & R.W. Gemmell	
May 16	0825-0840	W. Shoal Lake	ENE	5/1000±	500-800	D.G. Raveling	
May 16	0830-1130	Winnipeg & Environs	Nerly	4/-	1000-1500	R.C. Hutchinson	air survey: Morris-Arnaud-Dominion City-Letellier
May 16	0830-1045	Falcon River	NE	many/-	-	C. Dixon	few flocks if any after this period
May 16	0900-1125	Carman	NE	-/>5000	>2,000	W. Banting & J. Hines	
May 16	0900-1100	130 mi. NE of Winnipeg	NE	many/-	2-3000	J. Conway	60-300 birds/flock
May 16	1020	Lockport	-	-/-	1700	G.H. Townsend	
May 16	Morning	Carman-Killarney	NE	10-12/-	-	G.D. Adams	
May 16	Morning	Red River Delta	-	"thousands of geese"	-	M.R. McLandress	

Table 1. Cont'd.

Date (1970)	Period (C.S.T.)	Location	Estimated Direction of Migration	Nos. of Flocks/ Birds	Estimated Height (ft. a.g.l.)	Observer	Remarks
May 16	Morning	Marshy Pt.	NE	-/-	-	L. King	"more birds and greater altitudes than yesterday"
May 16	to mid-day	Richer	NNE	"hundreds of flocks"	-	S.A. McIvor	
May 16	1800	Winnipeg	N	-/-	-	A. Montgomery	
May 16	2100-2300	Beaver Creek	-	"many thousands" of geese	-	H. Mossop	
May 16	1900	Winnipeg	NE	-/-	-	R.W. Sutton	"large flocks"
May 16	1930-2035	Winnipeg	NE	45/-	400-1900	R.W. Gemmell	
May 16	2010-2100	Delta	-	2/180	-	H. Libby	
May 16	2040-2130	Winnipeg	N	4/-	-	G.J. Smith	heard only
May 16	2052	Portage la Prairie	N	15-20,000 birds	2200-2300	ATC Tower	"large birds, not white"
May 16	Afternoon	50 mi. NW of Winnipeg	-	-/-	-	L. King	fewer birds than in morning
May 16	2300	Winnipeg	-	-/-	-	R.W. Sutton	flocks still calling, none seen
May 16	-	Steinbach	NE	-/thousands	-	M. Comeau	
May 16	-	Marchand	-	-/35,000	-	E. Sainsbury	

Table 1. Cont'd.

Date (1970)	Period (C.S.T.)	Location	Estimated Direction of Migration	Nos. of Flocks/ Birds	Estimated Height (ft. a.g.l.)	Observer	Remarks
May 16	-	Clandeboye	-	-/-	-	L. Couture	"mass migration"
May 17	0200	Balmoral	-	-/-	-	ATC Personnel	many heard
May 17	0345	Delta	-	2/-	-	H. Libby	heard only
May 17	0520	Winnipeg	-	1/-	-	D.G. Raveling	
May 17	0625-1000	Eriksdale	NE	1/150	1100	G.H. Townsend	
May 17	Early morning	Victoria Beach	NE	many/-	-	M.R. McLandress	one flock after another, at 1200 no birds left
May 17	0700-0900	Carman	-	-/-	-	W. Banting & J. Hines	1 flock seen circling slough on return to Winnipeg

Table 2. Some weather factors for Winnipeg International Airport. May 1 through 18, 1970.

Date	Time (C.S.T.)	Wind direction (°True N) & speed (kts)[a] Surface	1200' a.g.l.	3200' a.g.l.	Temp. (°F)	Precipitation[b]	Clouds Type[c]/Opacity	Total Opacity	Total Amount
May 1	0600	350/20[d]	-	-	26.7		Sc 7	7	10
"	1800	310/12	315/16	355/16	44.0		Cu 1	1	1
May 2	0600	200/15	250/28	235/22	36.6		Sc 8, Ac 2	8	9
"	1800	320/18	320/20	305/24	59.1		Sc 8, Ci 1	9	9
May 3	0600	280/03	320/21	300/20	39.0		Sc 6, Ac 1	7	8
"	1800	320/18	325/18	320/42	49.0		Cu 1	1	1
May 4	0600	00/00[e]	210/09	295/17	30.3		Ac 1	1	1
"	1800	360/14	-	-	40.7		Cu 6	6	6
May 5	0600	320/02	040/21	030/17	26.3			0	0
"	1800	160/09	140/15	150/09	48.6		Ac 1, Ci 1	2	6
May 6	0600	140/15	185/54	205/50	42.0		Sc 6, Ci 1	7	10
"	1800	170/23	180/32	230/39	69.7		Sc 1, Acc 1, Ac 1, Ci 1	4	7
May 7	0600	350/04	010/14	310/07	46.3		Ac 1, Ci 1	2	5
"	1800	040/28	025/35	005/30	59.6		Ac 1, Ci 6	6	9
May 8	0600	030/17	060/38	060/24	39.2		Ac 1, Ci 3	4	10
"	1800	050/29	055/35	070/35	58.0		Ac 6, Ci 2	8	10
May 9	0600	070/14	090/26	100/25	42.0		Sf 2, Sc 6, Ac 1	10	10
"	1800	080/18	-	-	47.9		Sc 9	9	9
May 10	0600	030/15	-	-	35.9		Sf 2, Sf 5, Sc 3	10	10
"	1800	120/17	110/28	075/30	40.6		Sc 10	10	10
May 11	0600	100/15	090/26	120/18	35.9		Sc 8	8	9
"	1800	110/16	100/24	-	40.8	RW⁻	St 2, Sc 8	10	10

Table 2. Cont'd.

Date	Time (C.S.T.)	Wind direction (°True N) & speed (kts)[a] Surface	1200' a.g.l.	3200' a.g.l.	Temp. (°F)	Precipitation[b]	Type[c]/Opacity	Total Opacity	Total Amount
May 12	0600	020/10	-	-	36.0	L^{--}, F	Sf 1, Sf 7, Sf 2	10	10
"	1800	090/12	-	-	43.0		Sc 10	10	10
May 13	0600	070/11	-	-	38.0		Sc 7, Sc 2	9	10
"	1800	00/00	-	-	48.2		Sc 8, Ac 1	9	10
May 14	0600	040/09	090/16	075/09	41.9	R^{-}	Sf 3, Sc 5, As 2	10	10
"	1800	050/07	-	-	44.0		Sc 5, Sc 5	10	10
May 15	0600	360/12	-	-	40.0	R^{-}, F	Sf 1, Sf 7, Sc 2	10	10
"	1800	030/10	010/18	355/23	46.2	RW^{--}	Sc 8, Ac 2	10	10
May 16	0600	290/10	340/28	345/23	38.7			0	0
"	1800	300/14	315/16	320/17	65.1		Cu 1	1	1
May 17	0600	170/17	220/28	215/19	49.4		Cu 1, Ci 1	2	5
"	1800	250/16	245/34	250/30	84.2		Ac 1, Cs 1	2	6
May 18	0600	300/09	330/31	305/18	51.0		Acc 1, Ac 1, Ci 1	3	4
"	1800	310/19	310/31	290/26	60.4		Sc 1, Ci 1	2	5

[a]kts = knots; 1 knot = 1 nautical mile per hour = 1.15 statute mile per hour = 1.852 KM per hour = .514 meter per second.

[b]RW^{-} = light rainshowers, RW^{--} = very light rainshowers, R^{-} = light rain, F = fog, L^{--} = very light drizzle.

[c]St = stratus, Cu = cumulus, Sf = stratofractus, Ac = altocumulus, Acc = altocumulus castellanus, Ci = cirrus.

[d]350/20 = wind from 350° at 20 kts.

[e]00/00 = calm

Table 3. Surface and upper air wind measurements for Winnipeg International Airport. May 14 through May 18, 1970.

Date	Time (C.S.T.)	Surface	1200' a.g.l.[a]	2200' a.g.l.	3200' a.g.l.	4200' a.g.l.	5200' a.g.l.	6200' a.g.l.
May 14	0000	350/03[b]	090/07	145/13	190/10	-	-	-
"	0600	040/09	090/16	075/08	075/09	140/02	090/04	095/05
"	1200	050/09	-	-	-	-	-	-
"	1800	050/07	-	-	-	-	-	-
May 15	0000	030/09	-	-	-	-	-	-
"	0600	360/12	-	-	-	-	-	-
"	1200	020/20	-	-	-	-	-	-
"	1800	030/10	010/18	360/20	355/23	355/24	-	-
May 16	0000	270/10	315/13	330/17	340/21	340/25	345/24	345/28
"	0600	290/10	340/28	340/26	345/23	345/25	345/24	345/28
"	1200	310/16	310/10	310/09	320/15	340/17	340/19	345/22
"	1800	300/14	315/16	310/16	310/17	325/17	320/21	315/26
May 17	0000	190/09	205/15	225/09	300/04	285/09	280/21	305/26
"	0600	170/17	220/28	220/24	215/19	225/13	245/17	260/17
"	1200	180/22	195/30	230/38	230/48	235/32	240/30	235/40
"	1800	250/16	245/34	255/31	250/30	250/27	255/25	265/35
May 18	0000	270/12	325/22	330/20	310/22	300/28	290/30	285/34
"	0600	300/09	330/31	330/25	305/18	295/37	285/22	280/28
"	1200	280/17	280/14	280/16	280/30	275/35	265/41	260/41
"	1800	310/19	310/31	310/26	290/26	290/22	280/21	300/29

[a] a.g.l.: above ground level

[b] 350/03: wind from 350° at 3 kts. 1 knot = nautical mile per hour = 1.15 statute mile per hour = 1.852 KM per hour = .514 meter per second.

Table 4. Hourly numbers of 'goose echoes' crossing a 50 n. mi. line during the main wave of snow goose migration (see text). Winnipeg, spring 1970.

Period (CST)	Number of 'goose echoes' per hour		
	May 15	May 16	May 17
0000-0100		168	179
0100-0200		132[b]	150
0200-0300		58	172
0300-0400		60	63
0400-0500		24	32[b]
0500-0600		11	85
0600-0700		8	58
0700-0800		No Data	29
0800-0900		40[a]	21
0900-1000		42	6
1000-1100		65	
1100-1200		41	
1200-1300		27	
1300-1400		16	
1400-1500		15	
1500-1600	2	37	
1600-1700	2	9	
1700-1800	2	12	
1800-1900	0	8	
1900-2000	0[a]	77	
2000-2100	1	154	
2100-2200	11	186	
2200-2300	35	346[b]	
2300-2400	118	210[c]	

[a]Estimate based on 45 minutes of radar film
[b]Estimate based on 30 minutes of radar film
[c]Estimate based on 50 minutes of radar film

Table 5. Directions of 'goose echoes' during the main wave of snow goose migration (see text for terminology). Winnipeg, spring 1970.

Date (1970)	Period (CST)	Direction of movement of 'goose echoes' Mean (°True N)	Range (°True N)	S. D.	N
May 15	1300-1400[a]	73.6	69-77	3.8	4
"	1400-1500[a]	72.6	55-88	9.7	12
"	1500-1600[a]	73.1	57-88	8.9	14
"	1600-1700[a]	72.6	48-83	13.5	14
"	1700-1800	79.8	56-90	12.6	13
"	1800-1900	73.3	50-88	12.2	9
"	1900-1945	61.4	38-86	13.1	10
"	2000-2100	64.3	47-74	7.9	14
"	2100-2200	72.4	63-88	7.5	18
"	2200-2300	71.7	59-87	7.1	34
"	2300-2400	74.3	52-90	7.6	38
May 16	0000-0030	76.2	61-90	8.2	48
"	0130-0200	77.0	51-90	8.9	42
"	0200-0300	80.8	60-90	6.3	53
"	0300-0400	75.2	54-90	9.5	44
"	0400-0500	71.7	41-88	9.8	50
"	0500-0600	71.0	58-90	9.4	29
"	0600-0700	70.2	46-88	9.1	51
"	0700-0830	-	-	-	-
"	0830-0900	49.3	4-64	12.6	36
"	0900-1000	45.2	12-78	13.0	36
"	1000-1100	40.3	2-59	14.7	43

Table 5. Cont'd.

Date (1970)	Period (CST)	Direction of movement of 'goose echoes'			
		Mean (°True N)	Range (°True N)	S. D.	N
May 16	1100-1200	45.6	10-70	16.9	41
"	1200-1300	52.9	1-78	16.0	29
"	1300-1400	48.7	4-83	21.4	35
"	1400-1500	43.0	3-71	21.8	27
"	1500-1600	50.3	6-76	16.4	35
"	1600-1700	59.1	38-75	9.0	21
"	1700-1800	46.0	0-83	16.7	26
"	1800-1900	46.7	16-80	13.0	43
"	1900-2000	40.8	18-72	13.0	63
"	2000-2100	40.3	17-81	13.0	60
"	2100-2200	35.6	14-64	8.2	61
"	2200-2230	38.5	18-52	7.8	26
"	2300-2400	34.5	6-59	11.8	77
May 17	0000-0100	36.7	17-58	9.7	61
"	0100-0200	36.1	18-56	9.4	52
"	0200-0300	36.0	22-59	7.8	35
"	0300-0400	34.7	12-59	11.5	32
"	0400-0430	30.3	12-40	5.1	46
"	0500-0600	30.7	16-42	6.3	45
"	0600-0700	35.0	20-43	6.7	18
"	0700-0800	24.9	12-39	7.6	22
"	0800-0900	27.7	0-59	13.1	29
"	0900-1000	15.7	5-31	8.7	9

[a]Directions obtained using Vanguard Film Analyzer.

Table 6. Height of echoes presumed to be caused by flocks of snow geese as indicated on the Precision Approach Radar at Winnipeg International Airport. Spring 1970.

Date (1970)	Period (CST)	Height (band) with at least 50% of the echoes (feet a.g.l.)	Range (feet a.g.l.)		N	Direction
May 15	1900-2230[a]	1200-1400	-	-	10 +	Eerly
"	2231-2250	1100-1300	1100	4200	4	Eerly
"	2251-2345	1200	700	>2800	9	Eerly
May 16	1500-1929[a]	about 1200	-	4200	many	-
"	1930-1948	1100-1200	400	1200	14	NE
"	1949-2040[b]	1100-1200	400	1900	24[c]	NE
"	2041-2110	1200	0	2200	20	NE
"	2111-2140	1200-1500	600	3000	31	NE
"	2141-2210	1200-1800	1200	>3700	8	NE
"	2211-2248	1000-1500	1000	>3300	18	NE

[a]Observations by PAR operator.

[b]Period during which coordinated visual observations were made from the ATC tower.

[c]Of the 16 echoes at ranges less than 5 n. mi. 11 were visually confirmed as goose flocks.

Table 7. Tailwind components of the winds from surface to 6200 ft. a.g.l. during snow goose migration over Winnipeg. Spring 1970.

	Period (CST)	Tailwind components (kts) at different heights (ft. a.g.l.)						
		0'	1200'	2200'	3200'	4200'	5200'	6200'
May 15	2300-2400	+9.6	+6.2	+ 4.1	+1.5	+1.7	- .3	- .4
May 16	1700-1800	+3.8	+ .2	+ 1.7	+1.8	-2.5	-1.5	+0.5
May 16	2300-2400	+8.2	+13.8	+ 8.8	+ .3	+3.1	+8.8	0

+: direction of tailwind component is the same as that of the 'goose echoes'.

-: direction of tailwind component is opposite to that of the 'goose echoes'.

Table 8. Ground speeds of goose echoes during the main wave. Winnipeg, spring 1970.

Date	(CST)	Ground speed of 'goose echoes' Mean (kts)a	Extremes (kts)		S.D.	N
May 15	1300-1400	25.3	24	28	1.	4
"	1400-1500	24.3	20	28	2.3	12
"	1500-1600	26.5	19	34	4.8	13
"	1600-1700	27.2	17	42	7.6	13
"	1700-1800	31.3	17	42	7.1	12
"	2300-2400	31.9	17	39	4.2	40
May 16	0500-0600	29.5	24	37	4.2	11
"	1100-1200	27.2	22	32	2.5	43
"	1700-1800	31.5	27	40	4.0	17
"	2200-2300	39.7	31	49	3.8	32
"	2300-2400	40.6	32	50	4.0	42
May 17	0500-0600	57.2	53	70	4.3	21
"	0600-0700	53.5	45	65	4.6	27
"	0700-0800	59.9	52	73	6.1	14
"	0800-0900	61.4	54	71	6.3	5
"	0900-1000	62.3	59	67	4.2	3

[a] 1 knot = 1 nautical mile per hour = 1.151 statute miles per hour 1.852 km per hour = .514 meter per second.

Toble 9. Mean ground speeds, directions, air speeds and headings of migrating snow geese. Winnipeg, spring 1970.

Date (1970)	Period (CST)	Mean ground speed[a] (kts)	Mean direction (°N)	Wind direction (°N) and speed (kts) at flight height	Mean air speed (kts)	Mean heading (°N)
May 15	2300-2400	31.8	76	315/13	27.5	52
May 16	1100-1200	27.2	49	310/70	29.1	20
May 16	1700-1800	31.5	53	315/16	33.3	24
May 16	2300-2400	40.6	42	205/15	26.6	52
May 17	0500-0600	57.2	33	220/28	29.6	27

[a]As determined with the Vanguard Motion Analyzer